

## CHAPTER 4

# PESTICIDE FORMULATIONS

### LEARNING OBJECTIVES

After studying this chapter, you should:

- Understand what a pesticide formulation is.
- Know how to interpret common abbreviations used to describe formulations (e.g., WP, DF, EC, RTU, S, G, ULV).
- Know how to identify advantages and disadvantages of common formulation types (e.g., dusts, granules, wettable powders, dry flowables, microencapsulated, aerosols).
- Know how to explain the role of adjuvants (e.g., buffers, stickers, spreaders) during pesticide application.



**P**esticide chemicals in their “raw” or unformulated state are not usually suitable for pest control. These concentrated chemicals (**active ingredients**) may not mix well with water, may be chemically unstable, and may be difficult to handle and transport. For these reasons, manufacturers add inert substances such as clays and solvents to improve application effectiveness, safety, handling, and storage. **Inert ingredients** do not possess pesticidal activity and are added to serve as a carrier for the active ingredient. The mixture of active and inert ingredients is called a **pesticide formulation**. This formulation may consist of:

- The pesticide active ingredient that controls the target pest.
- The carrier, such as an organic solvent or mineral clay.
- Surface-active ingredients, such as stickers and spreaders.

- Other ingredients, such as stabilizers, dyes, and chemicals that improve or enhance pesticidal activity.

Usually you need to mix a formulated product with water or oil for final application. Baits, granules, gels, and dusts, however, are ready for use without additional dilution. Manufacturers package many specialized pesticides, such as products for households, in ready-to-use formulations.

A single active ingredient often is sold in several kinds of formulations. Abbreviations are often used to describe the formulation (e.g., WP for wettable powders); how the pesticide is used (e.g., TC for termiticide concentrate); or the characteristics of the formulation (e.g., LO for a low-odor formulation). The amount of active ingredient (a.i.) and the kind of formulation are listed on the product label. For example, an 80% SP contains 80 percent by weight

**Table 4.1 Abbreviations for Formulations**

<b>A</b>	= Aerosol	<b>M</b>	= Microencapsulated
<b>AF</b>	= Aqueous flowable	<b>MTF</b>	= Multiple temperature formulation
<b>AS</b>	= Aqueous solution or aqueous suspension	<b>P</b>	= Pellets
<b>B</b>	= Bait	<b>PS</b>	= Pellets
<b>C</b>	= Concentrate	<b>RTU</b>	= Ready-to-use
<b>CM</b>	= Concentrate mixture	<b>S</b>	= Solution
<b>CG</b>	= Concentrate granules	<b>SD</b>	= Soluble dust
<b>D</b>	= Dust	<b>SG</b>	= Soluble granule
<b>DF</b>	= Dry flowables	<b>SP</b>	= Soluble powder or soluble packet
<b>DS</b>	= Soluble dust	<b>ULV</b>	= Ultra low volume
<b>E</b>	= Emulsifiable concentrate	<b>ULW</b>	= Ultra low weight or ultra low wettable
<b>EC</b>	= Emulsifiable concentrate	<b>W</b>	= Wettable powder
<b>F</b>	= Flowable (liquid)	<b>WDG</b>	= Water-dispersible granules
<b>G</b>	= Granules	<b>WP</b>	= Wettable powder
<b>GL</b>	= Gel	<b>WS</b>	= Water soluble
<b>L</b>	= Liquid (flowable)	<b>WSG</b>	= Water-soluble granules
<b>LC</b>	= Liquid concentrate or low concentrate	<b>WSL</b>	= Water-soluble liquid
<b>LV</b>	= Low volatile	<b>WSP</b>	= Water-soluble powder or water-soluble packet

of active ingredient and is a soluble powder. If it is in a 10-pound bag, it contains 8 pounds of a.i. and 2 pounds of inert ingredient. Liquid formulations indicate the amount of a.i. in pounds per gallon. For example, 4F means 4 pounds of the a.i. per gallon in a flowable formulation. Some common formulation abbreviations are listed in Table 4.1.

If you find that more than one formulation is available for your pest control situation, you should choose the best one for the job. Before you make the choice, ask yourself several questions about each formulation. For example:

- Do I have the necessary application equipment?

- Can the formulation be applied appropriately under the conditions in the application area?
- Will the formulation reach your target and stay in place long enough to control the pest?
- Is the formulation likely to damage the surface to which you will apply it?
- Could I choose a less hazardous formulation that would still be as effective?

To answer these kinds of questions, you need to know something about the characteristics of different types of formulations and the general advantages and disadvantages of each type.

## AN OVERVIEW OF THE FORMULATION PROCESS

**T**he ingredients in pesticide products come from many sources. Some, such as nicotine, pyrethrum, and rotenone, are extracted from plants. Others have a mineral origin (e.g., copper,

sulfur), while a few are derived from microbes (e.g., *Bacillus thuringiensis*). However, the vast majority of active ingredients are made in the laboratory. These synthetic active ingredients may

have been designed by a chemist or discovered through a screening process examining chemicals generated by various industries.

Regardless of their source, pesticide active ingredients have a range of solubilities. Some dissolve readily in water; others, only in oils. Some active ingredients may be relatively insoluble in either water or oil. Solubility characteristics and the intended use of the pesticide generally define which formulations best deliver the active ingredient.

Usually, an active ingredient is combined with appropriate inert materials prior to packaging. The brief review of basic chemical terminology below should prove helpful in understanding differences among the various types of formulations.

## Solution

A solution results when a substance is dissolved in a liquid. The components of a true solution cannot be mechanically separated. Once mixed, a true solution does not require agitation to keep its various parts from settling. Solutions are frequently transparent, although if they are dark colored, this may not be the case.

## Suspension

A suspension is a mixture of finely divided, solid particles dispersed in a

liquid. The solid particles do not dissolve in the liquid, and the mixture must be agitated to keep the particles evenly distributed. Most suspensions will have a cloudy, murky appearance. The label directs the user to shake well before using. Such products also form suspensions when mixed with water for application as a spray. Explicit label information describes the need for sufficient agitation to keep the solid particles of the product dispersed in the spray tank.

## Emulsion

An emulsion occurs when one liquid is dispersed (as droplets) in another liquid. Each liquid retains its original identity. Some degree of agitation generally is required to keep the emulsion from separating. Emulsions usually have a milky appearance. The active ingredient is dissolved in an oil-based solvent. When the product is mixed with water, an emulsion (oil in water) is formed. An emulsifying agent (often called an **emulsifier**) formulated into product helps prevent the emulsion from separating.

Familiarity with these terms and processes leads to a greater understanding and appreciation of the advantages and disadvantages of many commonly used pesticide formulations.

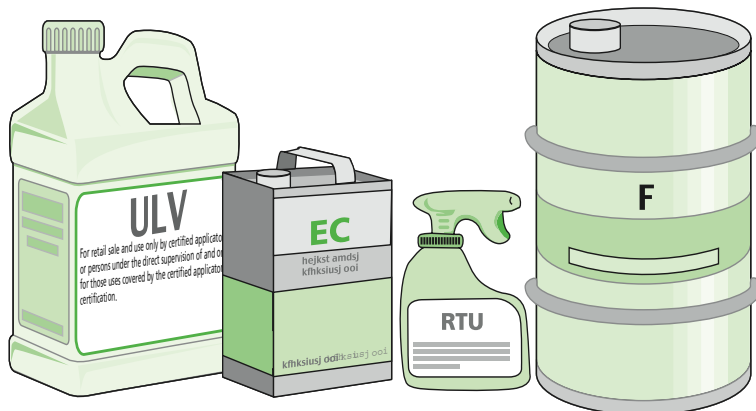
## LIQUID FORMULATIONS

**L**iquid formulations are generally mixed with water, but in some instances labels may permit the use of crop oil, diesel fuel, kerosene, or some other light oil as a carrier.

### Emulsifiable Concentrates (EC or E)

An emulsifiable concentrate formulation usually contains a liquid active ingredient, one or more petroleum-based solvents (which give EC formulations their strong odor), and an agent that allows the formulation to be mixed with water to form an emulsion. Most ECs contain between 25 and 75 percent (2 to 8 pounds) active ingredient

per gallon. ECs are among the most versatile formulations. They are used against agricultural, ornamental and turf, forestry, structural, food processing,



livestock, and public health pests. They are adaptable to many types of application equipment, from small, portable sprayers to hydraulic sprayers, low-volume ground sprayers, mist blowers, and low-volume aircraft sprayers.

**Advantages:**

- Relatively easy to handle, transport, and store.
- Little agitation required—will not settle out or separate when equipment is running.
- Not abrasive.
- Will not plug screens or nozzles.
- Little visible residue on treated surfaces.

**Disadvantages:**

- High a.i. concentration makes it easy to overdose or underdose through mixing or calibration errors.
- May cause damage to desirable plants (**phototoxicity**).
- Easily absorbed through skin of humans or animals.
- Solvents may cause rubber or plastic hoses, gaskets, and pump parts and surfaces to deteriorate.
- May cause pitting or discoloration of painted finishes.
- Flammable—should be used and stored away from heat or open flame.
- May be corrosive.

**Solutions (S)**

Some pesticide active ingredients dissolve readily in a liquid carrier such as water or a petroleum-based solvent. When mixed with the carrier, they form a solution that does not settle out or separate. Formulations of these pesticides usually contain the active ingredient, the carrier, and one or more other ingredients. Solutions may be used in any type of sprayer, indoors or outdoors.

**Ready-to-use Low-concentrate Solutions (RTU)**

Low-concentrate formulations are ready to use and require no further dilution before application. They consist of a small amount of active ingredient (often 1 percent or less per unit volume) dissolved in an organic solvent. They usually do not stain fabrics or have unpleasant odors. They are especially useful for structural and institutional pests and for household use. Major disadvantages of low-concentrate formulations include limited availability and high cost per unit of active ingredient. Many organic solvents are harmful to foliage, so they often cannot be used as plant sprays.

**Ultra-low Volume (ULV)**

These concentrates may approach 100 percent active ingredient. They are designed to be used as is or to be diluted with only small quantities of a specified carrier and are used at rates of no more than 1/2 gallon per acre. These special purpose formulations are used mostly in outdoor applications, such as in agricultural, forestry, ornamental, and mosquito control programs.

**Advantages:**

- Relatively easy to handle, transport, and store.
- Remain in solution; little agitation required.
- Not abrasive to equipment.
- Will not plug screens and nozzles.
- Leave little visible residue on treated surfaces.

**Disadvantages:**

- Difficult to keep pesticide on target—high drift hazard.
- Specialized equipment required.
- Easily absorbed through skin of humans or animals.
- Solvents may cause rubber or plastic hoses, gaskets, and pump parts and surfaces to deteriorate.
- Calibration and application must



be done very carefully because of the high concentration of active ingredient.

## Invert Emulsions

An invert emulsion contains a water-soluble pesticide dispersed in an oil carrier. Invert emulsions require a special kind of emulsifier that allows the pesticide to be mixed with a large volume of petroleum-based carrier, usually fuel oil. Invert emulsions aid in reducing drift. With other formulations, some spray drift results when water droplets begin to evaporate before reaching target surfaces; as a result, the droplets become very small and light. Because oil evaporates more slowly than water, invert emulsion droplets shrink less; therefore, more pesticide reaches the target. The oil helps to reduce runoff and improves rain resistance. It also serves as a sticker-spreader by improving surface coverage and absorption. Because droplets are relatively large and heavy, it is difficult to get thorough coverage on the undersides of foliage. Invert emulsions are most commonly used along rights-of-way where drift to susceptible non-target plants or sensitive areas can be a problem.

## Flowables (F)/Liquids (L)

A flowable or liquid formulation combines many of the characteristics of emulsifiable concentrates and wettable powders. Manufacturers use these formulations when the active ingredient is a solid that does not dissolve in either water or oil. The active ingredient, impregnated on a substance such as clay, is ground to a very fine powder. The powder is then suspended in a small amount of liquid. The resulting liquid product is quite thick. Flowables and liquids share many of the features of emulsifiable concentrates, and they have similar disadvantages. They require moderate agitation to keep them in suspension and leave visible residues, similar to those of wettable powders.

Flowables/liquids are easy to handle and apply. Because they are liquids, they are subject to spilling and splashing. They contain solid particles, so they contribute to abrasive

wear of nozzles and pumps. Flowable and liquid suspensions settle out in their containers. Always shake them thoroughly before pouring and mixing. Because flowable and liquid formulations tend to settle, manufacturers package them in containers of 5 gallons or less to make remixing easier.

## Aerosols (A)

These formulations contain one or more active ingredients and a solvent. Most aerosols contain a low percentage of active ingredients. There are two types of aerosol formulations—the ready-to-use type commonly available in pressurized sealed containers, and those products used in electrical or gasoline-powered aerosol generators that release the formulation as a “smoke” or “fog.”

### Ready-to-use Aerosols

These formulations are usually small, self-contained units that release the pesticide when the nozzle valve is triggered. The pesticide is driven through a fine opening by an inert gas under pressure, creating fine droplets. These products are used in greenhouses, in small areas inside buildings, or in localized outdoor areas. Commercial models, which hold 5 to 10 pounds of pesticide, are usually refillable.

#### Advantages:

- Ready to use.
- Portable.
- Easily stored.
- Convenient way to buy a small amount of a pesticide.
- Retain potency over fairly long time.

#### Disadvantages:

- Practical for only very limited uses.
- Risk of inhalation injury.
- Hazardous if punctured, overheated, or used near an open flame.
- Difficult to confine to target site or pest.



## Formulations for Smoke or Fog Generators

These aerosol formulations are not under pressure. They are used in machines that break the liquid formulation into a fine mist or fog (aerosol) using a rapidly whirling disk or heated surface. These formulations are used mainly for insect control in structures such as greenhouses and warehouses and for mosquito and biting fly control outdoors.

### Advantages:

- Easy way to fill entire enclosed space with pesticide.

### Disadvantages:

- Highly specialized use and equipment.
- Difficult to confine to target site or pest.
- May require respiratory protection to prevent risk of inhalation injury.

## Liquid Baits

An increasing number of insecticides and rodenticides are being formulated as liquid baits. Liquid rodenticides are mixed with water and placed in bait stations designed for these products. They have two major benefits. Liquid rodenticides are effective in controlling rodents, especially rats, in areas where they cannot find water. They are also effective in areas of poor sanitation where ready availability of food renders traditional baits ineffective.

Liquid insecticide baits are used primarily by the structural pest control industry for controlling ants and, to a lesser extent, cockroaches. They are packaged as ready-to-use, sugar-based liquids placed inside bait stations. Liquid insecticide ant baits have a number of advantages. They are very effective against certain species of sugar-feeding ants. These ants typically accept and transfer liquid baits into the ant colonies. However, some ants will not feed on liquid baits. Liquid baits also must be replaced often.

## DRY OR SOLID FORMULATIONS

**D**ry formulations can be divided into two types: ready-to-use and concentrates that must be mixed with water to be applied as a spray.



### Dusts (D)

Most dust formulations are ready to use and contain a low percentage of active ingredients (usually 10 percent or less by weight), plus a very fine, dry inert carrier made from talc, chalk, clay,

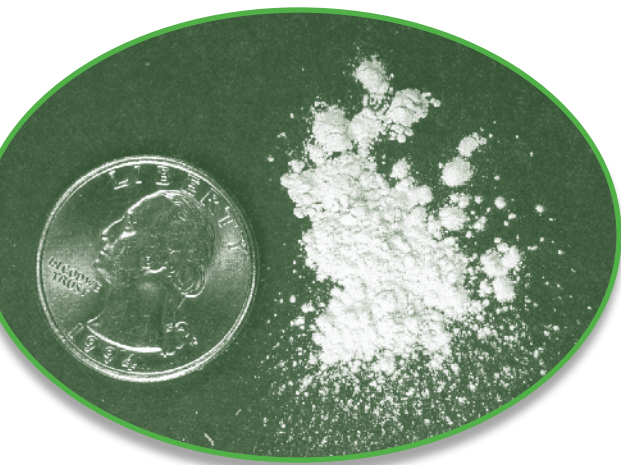
nut hulls, or volcanic ash. The size of individual dust particles varies.

A few dust formulations are concentrates and contain a high percentage of active ingredients. Mix these with dry inert carriers before applying.

Dusts are always used dry and can easily drift to non-target sites. They are widely used as seed treatments and sometimes for agricultural applications. In structures, dust formulations are used in cracks and crevices and for spot treatments to control insects such as cockroaches. Insects ingest poisonous dusts during grooming or absorb the dusts through their outer body covering. Dusts also are used to control lice, fleas, and other parasites on pets and livestock.

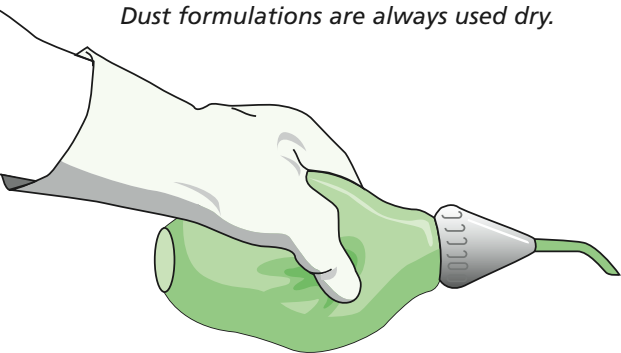
### Advantages:

- Most are ready to use, with no mixing.



Arlene Blessing, Purdue Pesticide Programs

*Dust formulations are always used dry.*



*A bulb duster used for applying dust formulations to cracks, crevices, and voids in buildings.*

- Effective where moisture from a spray might cause damage.
- Require simple equipment.
- Effective in hard-to-reach indoor areas.

#### **Disadvantages:**

- Easily drift off target during application.
- Residue easily moved off target by air movement or water.
- May irritate eyes, nose, throat, and skin.
- Will not stick to surfaces as well as liquids.
- Dampness can cause clogging and lumping.
- Difficult to get an even distribution of particles on surfaces.

## **Tracking Powders**

Special dusts known as tracking powders are used for rodent and insect monitoring and control. For rodent control, the tracking powder consists of finely ground dust combined with a stomach poison. Rodents walk through the dust, pick it up on their feet and fur, and ingest it when they clean themselves. Tracking powders are useful when bait acceptance is poor because of an abundant, readily available food supply. Non-toxic powders, such as talc or flour, often are used to monitor and track the activity of rodents in buildings.

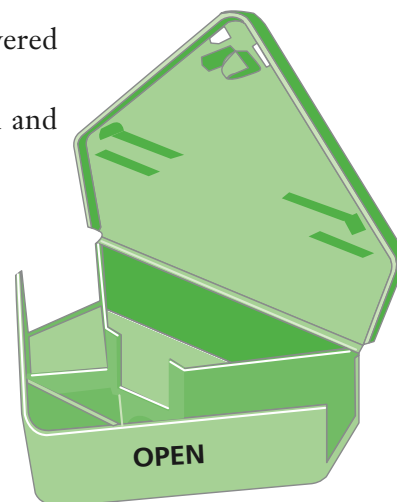
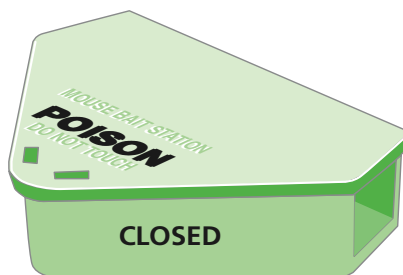
## **Baits (B)**

A bait formulation is an active ingredient mixed with food or another attractive substance. The bait either attracts the pests or is placed where the pests will find it. Pests are killed by eating the bait that contains the pesticide. The amount of active ingredient in most bait formulations is quite low, usually less than 5 percent.

Baits are used inside buildings to control ants, roaches, flies, other insects, and rodent control. Outdoors they sometimes are used to control snails, slugs, and insects such as ants and termites. Their main use is for control of vertebrate pests such as rodents, other mammals, and birds.

#### **Advantages:**

- Ready to use.
- Entire area need not be covered because pest goes to bait.
- Control pests that move in and out of an area.



*A bait station used in rodent control in the closed and open positions. Bait formulations are placed inside the tamper-resistant station.*

### Disadvantages:

- Can be attractive to children and pets.
- May kill domestic animals and non-target wildlife outdoors.
- Pest may prefer the crop or other food to the bait.
- Dead vertebrate pests may cause odor problem.
- Other animals may be poisoned as a result of feeding on the poisoned pests.
- If baits are not removed when the pesticide becomes ineffective, they may serve as a food supply for the target pest or other pests.

### Pastes, Gels, and Other Injectable Baits

Pastes and gels are mainly used in the pest control industry for ants and cockroaches. Insecticides formulated as pastes and gels are now the primary formulations used in cockroach control. They are designed to be injected or placed as either a bead or dot inside small cracks and crevices of building elements where insects tend to hide or travel. Two basic types of tools are used to apply pastes and gels—syringes and bait guns. The applicator forces the bait out of the tip of the device by applying pressure to a plunger or trigger.

### Advantages:

- They are odorless, produce no vapors, have low human toxicity, and last for long periods.
- Applicator exposure is minimal.
- Hidden placements minimize human and pet exposure.
- Very accurate in their placement and dosage.
- Easily placed in insect harborage for maximum effectiveness.

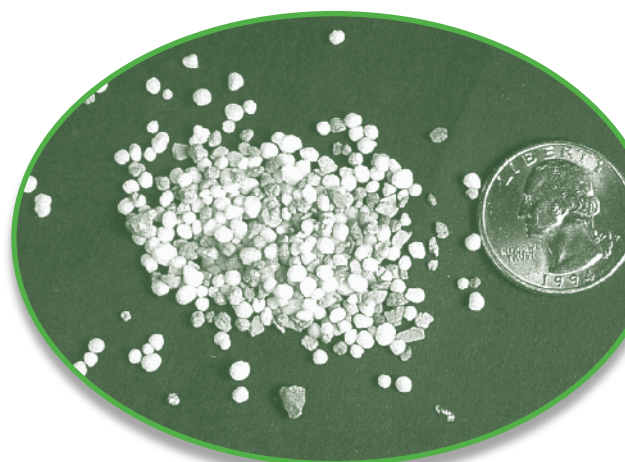
### Disadvantages:

- Can become contaminated from exposure to other pesticides and cleaning products.

- When exposed to high temperatures, gels can run and drip.
- May stain porous surfaces.
- Repeated applications can cause an unsightly buildup of bait.

### Granules (G)

Granular formulations are similar to dust formulations except granular particles are larger and heavier. The coarse particles are made from materials such as clay, corncobs, or walnut shells. The active ingredient either

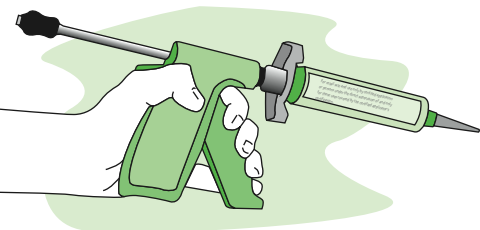


Arlene Blessing, Purdue Pesticide Programs

*Granular formulations are larger and heavier than dust formulations.*

coats the outside of the granules or is absorbed into them. The amount of active ingredient is relatively low, usually ranging from 1 to 15 percent by weight.

Granular pesticides are most often used to apply chemicals to the soil to control weeds, nematodes, and insects living in the soil, or for absorption into plants through the roots. Granular formulations are sometimes applied by airplane or helicopter to minimize drift or to penetrate dense vegetation. Once applied, granules release the active ingredient slowly. Some granules require soil moisture to release the active ingredient. Granular formulations also are used to control larval mosquitoes and other aquatic pests. Granules are used in agricultural, structural, ornamental, turf, aquatic, right-of-way, and public health (biting insect) pest control operations.



*A bait gun used by the pest control industry to treat small cracks and crevices.*



### Advantages:

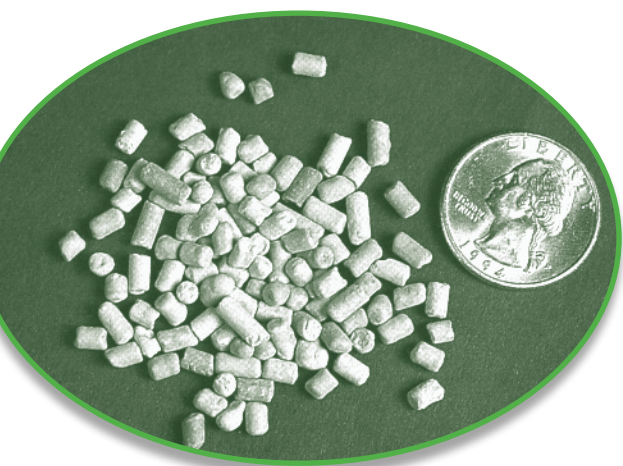
- Ready to use—no mixing.
- Drift hazard is low, and particles settle quickly.
- Little hazard to applicator—no spray, little dust.
- Weight carries the formulation through foliage to soil or water target.
- Simple application equipment needed, such as seeders or fertilizer spreaders.
- May break down more slowly than WPs or ECs because of a slow-release coating.

### Disadvantages:

- Often difficult to calibrate equipment and apply uniformly.
- Will not stick to foliage or other uneven surfaces.
- May need to be incorporated into soil or planting medium.
- May need moisture to activate pesticide.
- May be hazardous to non-target species, especially waterfowl and other birds that mistakenly feed on the seedlike granules.
- May not be effective under drought conditions because the active ingredient is not released in sufficient quantity to control the pest.

### Pellets (P or PS)

Most pellet formulations are very similar to granular formulations; the



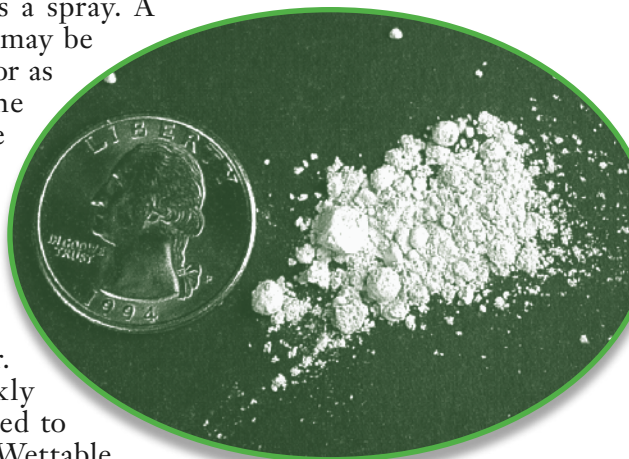
terms often are used interchangeably. In a pellet formulation, however, all the particles are the same weight and shape. The uniformity of the particles allows use with precision application equipment. A few fumigants are formulated as pellets. However, these are clearly labeled as fumigants. Do not confuse them with non-fumigant pellets.

### Wettable Powders (WP or W)

Wettable powders are dry, finely ground formulations that look like dusts. They usually must be mixed with water for application as a spray. A few products, however, may be applied either as a dust or as a wettable powder—the choice is left to the applicator. Wettable powders contain 5 to 95 percent active ingredient by weight; usually 50 percent or more. The particles do not dissolve in water. They settle out quickly unless constantly agitated to keep them suspended. Wettable powders are one of the most widely used pesticide formulations. They can be used for most pest problems and in most types of spray equipment where agitation is possible. Wettable powders have excellent residual activity. Because of their physical properties, most of the pesticide remains on the surface of treated porous materials such as concrete, plaster, and untreated wood. In such cases, only the water penetrates the material.

### Advantages:

- Easy to store, transport, and handle.
- Less likely than ECs and other petroleum-based pesticides to cause unwanted harm to treated plants, animals, and surfaces.

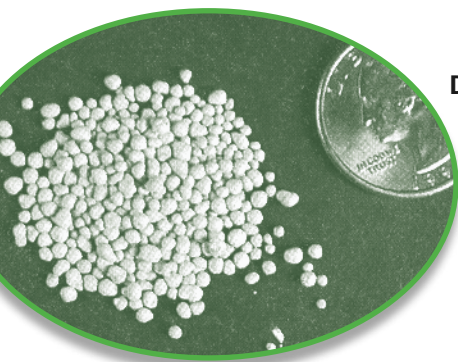


Arlene Blessing, Purdue Pesticide Programs

*Wettable powders are dry, finely ground formulations that look like dusts.*

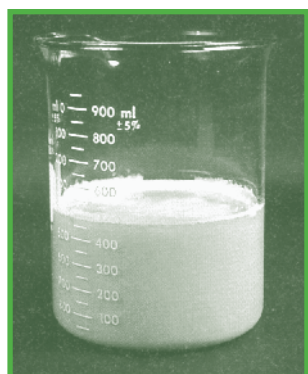
Arlene Blessing, Purdue Pesticide Programs

*In pellet formulations, all particles are the same weight and shape.*



Arlene Blessing, Purdue Pesticide Programs

*Water-dispersible granule before mixing.*



Arlene Blessing, Purdue Pesticide Programs

*Water-dispersible granule after mixing.*

- Easily measured and mixed.
- Less skin and eye absorption than ECs and other liquid formulations.

#### Disadvantages:

- Inhalation hazard to applicator while measuring and mixing the concentrated powder.
- Require good and constant agitation (usually mechanical) in the spray tank and quickly settle out if the agitator is turned off.
- Abrasive to many pumps and nozzles, causing them to wear out quickly.
- Difficult to mix in very hard, alkaline water.
- Often clog nozzles and screens.
- Residues may be visible on treated surfaces.

#### Soluble Powders (SP or WSP)

Soluble powder formulations look like wettable powders. However, when mixed with water, soluble powders dissolve readily and form a true solution. After they are mixed thoroughly, no additional agitation is necessary. The amount of active ingredient in soluble powders ranges from 15 to 95 percent

by weight; it usually is more than 50 percent. Soluble powders have all the advantages of wettable powders and none of the disadvantages except the inhalation hazard during mixing. Few pesticides are available in this formulation because few active ingredients are readily soluble in water.

#### Water-dispersible Granules (WDG) or Dry Flowables (DF)

Water-dispersible granules, also known as dry flowables, are like wettable powders except instead of being dustlike, they are formulated as small, easily measured granules. Water-dispersible granules must be mixed with water to be applied. Once in water, the granules break apart into fine particles similar to wettable powders. The formulation requires constant agitation to keep them suspended in water. The percentage of active ingredient is high, often as much as 90 percent by weight. Water-dispersible granules share many of the same advantages and disadvantages of wettable powders except:

- They are more easily measured and mixed.
- Because of low dust, they cause less inhalation hazard to the applicator during handling.

### OTHER FORMULATIONS

**O**ther formulations include chemicals that cannot be clearly classified as liquid or as dry/solid pesticide formulations.

#### Microencapsulated Materials

Manufacturers cover liquid or dry pesticide particles in a plastic coating to produce a microencapsulated formulation. Microencapsulated pesticides are mixed with water and sprayed in the same manner as other sprayable formulations. After spraying, the plastic coating breaks down and slowly releases the active ingredient. Microencapsulated materials have several advantages:

- Highly toxic materials are safer for applicators to mix and apply.
- Delayed or slow release of the active ingredient prolongs its effectiveness, allowing for fewer and less precisely timed applications.
- The pesticide volatilizes more slowly; less is lost from the application site.
- These formulations often reduce injury to plants.

In residential, industrial, and institutional applications, microencapsulated formulations offer several advantages. These include reduced odor,

release of small quantities of pesticide over a long time, and greater safety. Microencapsulated materials offer fewer hazards to the skin than ordinary formulations. Microencapsulated materials, however, pose a special hazard to bees. Foraging bees may carry microencapsulated materials back to their hives because they are about the same size as pollen grains. As the capsules break down, they release the pesticide, poisoning the adults and brood.

Breakdown of the microencapsulated materials to release the pesticide sometimes depends on weather conditions. Under certain conditions, the microencapsulated materials may break down more slowly than expected. This could leave higher residues of pesticide active ingredient in treated areas beyond normal restricted-entry or harvest intervals with the potential to injure fieldworkers. For this reason, regulations require long restricted-entry intervals for some microencapsulated formulations.

### Water-soluble Packets

Water-soluble packets reduce the mixing and handling hazards of some highly toxic pesticides. Manufacturers package precise amounts of wettable powder or soluble powder formulations in a special type of plastic bag. When you drop these bags into a filled spray tank, they dissolve and release their contents to mix with the water. There are no risks of inhaling or contacting the undiluted pesticide as long as you do not open the packets. Once mixed with water, pesticides packaged in water-soluble packets are no safer than other tank mixtures.

### Attractants

Attractants include **pheromones**, sugar and protein hydrolysate syrups, yeasts, and rotting meat. Pest managers use these attractants in sticky traps and capture bags. Attractants also can be combined with pesticides and sprayed onto foliage or other items in the treatment area.

### Impregnates

Manufacturers **impregnate**

(saturate) pet collars, livestock ear tags, adhesive tapes, plastic pest strips, and other products with pesticides. These pesticides evaporate over time, and the vapors provide control of nearby pests. Some paints and wood finishes have pesticides incorporated into them to kill insects or retard fungal growth. Fertilizers also may be impregnated with pesticides.

### Repellents

Various types of insect repellents are available in aerosol and lotion formulations. People apply these to their skin or clothing or to plant foliage to repel biting and nuisance insects. You can mix other types of repellents with water and spray them onto ornamental plants and agricultural crops to prevent damage from deer, dogs, and other animals.

### Animal Systemics

Systemic pesticides protect animals against fleas and other external blood-feeding insects as well as against worms and other internal parasites. A systemic animal pesticide is one that is absorbed and moves within the animal. These pesticides enter the animal's tissues after being applied orally or externally. Oral applications include food additives and premeasured capsules and liquids. External applications involve pour-on liquids, liquid sprays, and dusts. Most animal systemics are used under the supervision of veterinarians.

### Pesticide/Fertilizer Combinations

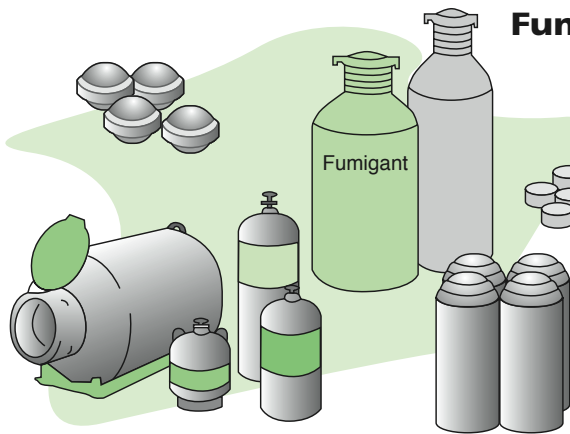
Pest managers frequently use insecticides, fungicides, and herbicides in combination with fertilizers. This provides a convenient way of controlling pests while fertilizing crops or lawns. Homeowners commonly use these combinations, although the unit cost of pesticide in these formulations is usually high. In commercial applications, dealers or growers custom mix pesticides with fertilizers to meet specific crop requirements.



M.J. Weaver, Virginia Tech Pesticide Programs

*Adding water-soluble packet to a spray tank.*





## Fumigants

Fumigants are pesticides that form poisonous gases when applied. Some active ingredients are liquids when packaged under high pressure and change to gases when they are released. Other active ingredients are volatile

liquids when enclosed in an ordinary container and therefore are not formulated under pressure. Others are solids that release gases when applied under conditions of high humidity or in the presence of water vapor. Fumigants are used for structural pest control, in food and grain storage facilities, and in regulatory pest control at ports of entry and at state and national borders. In agricultural pest control, fumigants are

used in soil, greenhouses, granaries, and grain bins.

### Advantages:

- Toxic to a wide range of pests.
- Can penetrate cracks, crevices, wood, and tightly packed areas such as soil or stored grains.
- Single treatment usually kills most pests in treated area.

### Disadvantages:

- The target site must be enclosed or covered to prevent the gas from escaping.
- Non-specific—highly toxic to humans and all other living organisms.
- Require the use of specialized protective equipment, including respirators specifically approved for use with fumigants.

*Fumigants are packaged in liquid and solid forms. Both turn into poisonous gases when applied.*

## PESTICIDE MIXTURES



Edward Crow, Maryland Department of Agriculture

*Incompatibility is a condition that prevents pesticides from mixing together properly to form a uniform solution or suspension.*

**C**ombining two or more pesticides and applying them at the same time is convenient and cost effective. Most pesticide manufacturers sell some of their products as premixes, but often you must still combine two or more pesticides at the time of application. When you combine mixtures of two or more pesticides and/or fertilizers at the time of application, you create a **tank mix**. A common tank mix involves combining fungicides with insecticides as a spray for tree fruit crops.

Another involves combining two or more herbicides to increase the number of weed species controlled. Some people mix pesticides with micronutrients or fertilizers. This practice saves money by reducing the time, labor, and fuel required for multiple applications. Tank mixes reduce equipment wear and decrease labor costs. They lessen the mechanical

damage done to crops and soil by heavy application equipment. Combinations may, however, affect the toxicity and the physical and chemical properties of any of the components of the tank mix increase residues, and damage or injure the target site, plant, or animal.

If you mix **DANGER—POISON** pesticides with **WARNING** or **CAUTION** pesticides, treat the mixture as a **DANGER—POISON** pesticide. You must use the required safety equipment and follow all other label restrictions found on the label having the greatest restrictions.

### Incompatibility

Incompatibility is a condition that prevents pesticides from mixing together properly to form a uniform solution or suspension. The formation of flakes, crystals, or oily clumps, or severe separation is unacceptable. Such incompatible mixtures clog application equipment and limit even distribution of the active ingredient in the spray



tank. This prevents good pesticide coverage.

The cause of incompatibility may be the chemical nature of the materials you are mixing. Impurities in the spray tank or water also may affect compatibility. Even the order in which you mix pesticides in the spray tank is important. Sometimes the types of formulations being mixed influence compatibility. Pesticide formulations of the same type are rarely incompatible with one another because they usually contain many of the same inert ingredients and solvents. Always evaluate a tank mixture by performing

the compatibility test described in Chapter 10.

Sometimes tank mixes seem compatible during testing and after mixing in the spray tank, but problems arise during application. This is known as **field incompatibility**. The temperature of the water in the tank can cause this problem. It could also be due to water impurities. Water pH (acidity vs. alkalinity) also may unexpectedly change for some unknown reason. Sometimes the amount of time the spray mixture has been in the tank causes field incompatibility.

## ADJUVANTS

**A**djuvants are chemicals that do not possess pesticidal activity. Adjuvants are either premixed in the pesticide formulation or added to the spray tank to improve mixing or application or to enhance pesticidal performance. They are used extensively in products designed for foliar applications. Adjuvants can be used to customize the formulation to specific needs and compensate for local conditions.

The right adjuvant may reduce or even eliminate spray application problems, thereby improving overall pesticide efficacy. Because adjuvants themselves have no pesticidal properties, they are not registered by the EPA. As a result, there is no set of standards for composition and quality, although some states have modified registration requirements for these chemicals and may require labels, technical data sheets, and efficacy information.

Before using any adjuvant, consult the pesticide label. Many registered pesticide products have very specific recommendations on their labels for use with one or more adjuvants. Failure to follow these instructions is as much a violation of the product label as inappropriate use of the pesticide.

If you have questions about the specific properties of an adjuvant, contact the manufacturer before attempting to use it. Companies that produce adjuvants can provide labels, technical data sheets, MSDS, supplemental labeling,

and promotional literature about their products.

Adjuvants are designed to perform specific functions, including wetting, spreading, sticking, reducing evaporation, reducing volatilization, buffering, emulsifying, dispersing, reducing spray drift, and reducing foaming. No single adjuvant can perform all these functions, but compatible adjuvants often can be combined to perform multiple functions simultaneously.

### Types of Adjuvants

Much of the confusion surrounding adjuvants can be attributed to the lack of understanding of adjuvant terminology. For example, many people use the terms **adjuvant** and **surfactant** interchangeably. These terms can refer to the same product because all surfactants are adjuvants. However, not all adjuvants are surfactants.

#### Surfactants

Surfactants, also called wetting agents and spreaders, physically alter the surface tension of a spray droplet. For a pesticide to perform its function properly, a spray droplet must be able to wet the foliage and spread out evenly over a leaf. Surfactants enlarge the area of pesticide coverage, thereby increasing the pest's exposure to the chemical. Surfactants are particularly important when applying a pesticide to waxy or hairy leaves. Without proper

#### TYPES OF ADJUVANTS

##### Surfactants

Wetting agents  
and spreaders

##### Stickers

##### Extenders

##### Plant penetrants

##### Compatibility agents

##### Buffers or pH modifiers

##### Drift retardants

##### Defoaming agents

##### Thickeners

wetting and spreading, spray droplets often run off or fail to cover leaf surfaces adequately. Too much surfactant, however, can cause excessive runoff and reduce pesticide efficacy.

Surfactants are classified by the way they ionize or split apart into electrically

charged atoms or molecules called ions. A surfactant with a negative charge is anionic. One with a positive charge is cationic, and one with no electrical charge is nonionic. Pesticidal activity in the presence of a non-ionic surfactant can be quite different from activity in the presence of a cationic or anionic surfactant. Selecting the wrong surfactant can reduce the efficacy of a pesticide product and injure the target plant. Anionic surfactants are most effective when used with contact pesticides (i.e., pesticides that control the pest by direct contact rather than being absorbed systemically). Cationic surfactants should never be used as stand-alone surfactants because they usually are phytotoxic.

Nonionic surfactants, often used with systemic pesticides, help pesticide sprays penetrate plant cuticles. Nonionic surfactants are compatible with most pesticides, and most EPA-registered pesticides that require a surfactant recommend a nonionic type.

### Stickers

A sticker is an adjuvant that increases the adhesion of solid particles to target surfaces. These adjuvants can decrease the amount of pesticide that washes off during irrigation or rain. Stickers also can reduce evaporation of the pesticide, and some slow down the degradation of pesticides by sunlight. Many adjuvants are formulated as spreader-stickers to make a general-purpose product.

### Extenders

Some adjuvant manufacturers

have named their products “extenders.” Extenders function like stickers by retaining pesticides longer on the target area, slowing evaporation, and inhibiting degradation by sunlight.

### Plant Penetrants

These adjuvants have a molecular configuration that enhances penetration of some pesticides into plants. An adjuvant of this type may increase penetration of a pesticide on one species of plant but not another. Enhanced penetration increases the activity of some pesticides.

### Compatibility Agents

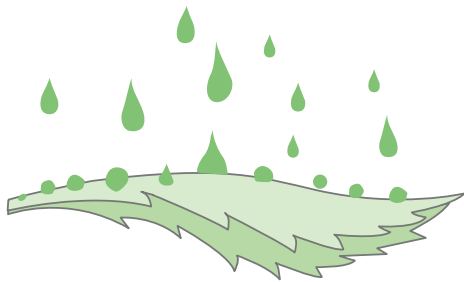
Pesticides are commonly combined with liquid fertilizers or other pesticides. Certain combinations can be physically or chemically incompatible, which causes clumps and uneven distribution in the tank. Occasionally the incompatible mixture plugs the pump and distribution lines resulting in expensive cleanup and repairs. A compatibility agent may eliminate these problems.

Read product label directions carefully before adding a compatibility agent to a spray mix. You may wish to do a compatibility test in a quart jar to determine the stability of the mixture. After adding the desired pesticides and the compatibility adjuvant to the jar, shake the mixture and then check for clumping, separation, thickening, and heat release. Any one of these signs indicates an incompatibility problem.

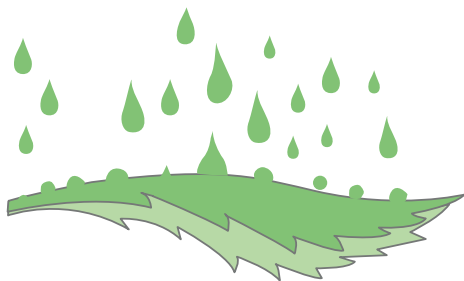
### Buffers or pH Modifiers

Most pesticide solutions or suspensions are stable between pH 5.5 and pH 7.0 (slightly acidic to neutral). Above pH 7.0 (alkaline or basic), the pesticide may be subject to degradation. Once a pesticide solution becomes alkaline, the risk exists that the pesticide degrades. Buffers and acidifiers are adjuvants that acidify and stabilize the water in the spray tank. Buffers must be added to the tank mix water first. The water must be neutralized or slightly acidified prior to adding pesticides and adjuvants

### Side view of leaf



Without surfactant



With surfactant

Adapted from Penn. State Pesticide Education Manual

**Figure 4.1**

*Surfactants increase the ability of the pesticide to spread evenly over the surface of a leaf or fruit.*

## Drift Control Additives

Drift is a function of droplet size. Small, fine drops with diameters of 100 microns or less tend to drift away from targeted areas. Drift control additives, also known as deposition aids, improve on-target placement of the pesticide spray by increasing the average droplet size. Drift reduction can be very important near sensitive sites and may well be worth the small reduction in efficacy that may result from the change in droplet size.

## Defoaming Agents

Some pesticide formulations create foam or a frothy “head” in spray tanks. This is often the result of both the type of surfactant used in the formulation and the type of spray tank agitation system. The foam usually can be reduced or eliminated by adding a small amount of a defoaming agent.

## Thickeners

As the name suggests, thickeners increase the viscosity (thickness) of spray mixtures. These adjuvants are used to control drift or slow evaporation after the spray has been deposited on the target area. Slowing evaporation is important when using systemic pesticides because they can penetrate the plant cuticle only as long as they remain in solution.

## How to Choose the Right Adjuvant

Many factors must be considered when choosing an adjuvant for use in a pest management program. Following are some guidelines:

- Use only adjuvants manufactured and marketed for agricultural or horticultural uses. Do not use industrial products or household detergents with pesticides because they may interfere with pesticide performance.
- Remember, there are no miracle adjuvants. It is generally wise to be skeptical of such claims as “keeps spray equipment clean” or

“causes better root penetration” unless the manufacturer has supporting evidence to back up such claims.

- Make sure the adjuvant has been thoroughly tested and proven effective for your intended use. Test questionable products on a limited area before proceeding with full-scale use.
- Certain pesticides and application procedures require certain types of adjuvants. Determine the correct type and use only an adjuvant of that type. For example, do not substitute an anionic surfactant when a nonionic surfactant is recommended.
- A particular pesticide label may require one or more adjuvants for a certain use yet prohibit any adjuvant for another use. Read the pesticide label carefully.
- Using an adjuvant is not always necessary. It is just as important to know when not to use an adjuvant as it is to know when to use one.

Spray adjuvants can contribute substantially to safe and effective pest control. Many spray adjuvants are available, each formulated to solve problems associated with a particular type of application. Check pesticide and adjuvant labels to make sure adjuvants are suitable for the site you plan to spray, the target pest, your equipment, and, of course, the pesticide you plan to use.

Remember, many pesticide products already contain an adjuvant. If a pesticide is already formulated properly for your crop, using an additional wetting agent, for example, may not give better spreading or coverage; instead, it could increase runoff, reduce deposit, and even severely damage the target plants.

## SUMMARY

**A** pesticide formulation consists of both active and inert ingredients. The active ingredient (a.i.) functions as the pesticide; the inert ingredient includes the carrier and adjuvants. The active ingredient includes always listed on the product label. The type of formulation may also be given. Persons handling pesticides must become familiar with the active ingredients and formulation types to better understand the nature of the products.

Pesticides are formulated in a variety of processes such as being dissolved in a solution or dispersed in a suspension or an emulsion. Many liquid and dry formulations are available, including emulsifiable concentrates (EC), solutions (S), flowables (F), dusts (D), baits (B), and soluble powders (SP), to mention a few. Other formulations are available that cannot be clearly classified as either liquid or dry/solid pesticide formulations. These products, such as microencapsulated materials and water-soluble packets, have special properties that make them preferable for certain pest control situations. Understanding the relative advantages and disadvantages of the various formu-

lation types helps the applicator decide which one is best to use in a given pest control situation.

Adjuvants are added to pesticide formulations to improve the pesticide's ability to control pests, although the adjuvants themselves do not possess pesticidal activity. For example, surfactant type adjuvants function as wetting agents or spreaders that improve pesticide coverage over an area such as a leaf surface. The pesticide handler should know how and when to use an adjuvant. Always read the pesticide label carefully to determine whether adding an adjuvant is recommended for use with the pesticide product.

In summary, the pesticide user must consider several factors when selecting a pesticide formulation, such as the risks associated with the formulation type, the practicality of using the formulation on the target site or pest, and whether it will provide effective control. Having a basic understanding of formulation types before using pesticides helps the user avoid mistakes and accidents in choosing, mixing, loading, and applying the product.